Red Queen Hypothesis [1]

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The Red Queen Hypothesis, named after the Red Queen in the book Alice in Wonderland, brings together two evolutionary theories.

The basis for the entire theory is down to 'the evolutionary arms race', where prey and predator constantly evolve together to reach some sort of uneasy balance.

An example of the Red Queen Hypothesis might be one of the plants that evolve toxins to kill off predators such as caterpillars [3].

If the plant, under predation selection pressure, evolved a new type of toxin to which the caterpillar had no immunity, most of the caterpillars would die off and the tree would flourish. This victory would be short lived, as only the caterpillars immune to the toxin, even if only a tiny percentage, would breed rapidly, and once again the tree would be under attack.

Sexual Reproduction and Genetics

For the Red Queen Hypothesis to happen, some sort of genetic mixing of genes must happen, such as sexual reproduction, as this throws up enough random fluctuations and mutations to allow new traits to appear. Most random mutations will disappear, as they confer no advantage or may even be detrimental.

Occasionally, they will give an advantage and will quickly spread through a population, as individuals with this genotype will have a competitive advantage. The industrial melanism [4] shown by the peppered moth [4] is an excellent example of this process in action. Without this mutation there would be a chance that the species may have become extinct.

If its population had shrunk, through predation or disease, to a small size, the species would have been open to environmental factors wiping it out.

Genetic fluctuations rely on probability and numbers. A large population is much more able, by chance, to throw up random mutations, whilst a small population is less likely.

Other Selection Pressures

Predator/prey relationships are not the only factors in the Red Queen Hypothesis.

If many species are competing for the same resources, mutations are sometimes needed to

prevent a species from being out-competed. This is possibly one of the reasons why sexual reproduction occurs in higher species. If no random mixing occurred, then a bacteria or parasite may quickly evolve into a lethal form which would wipe out a species.

Sexual reproduction means that in a large population, there would be enough individuals with resistance to breed, pass the trait on and continue the species.

In a strange way, this benefits both host and parasite because, if a parasite or bacteria was so effective that it killed the host species, then it too is guaranteed extinction.

This process of sexual selection may explain why the vast majority of genes in vertebrates are dormant and do nothing (often called ‘junk DNA’) as they are preserving possible mutations that might suddenly be needed in the future if the environment or parasite pressure changes.

Sickle Cell Anemia

Often, these genes can even be detrimental. In humanity, sickle cell anemia is a gene that causes the red blood cells of an individual to become sickle shaped and less able to carry oxygen.

If both of an individual’s parents pass on the gene, the individual will have the full blown disease and, without medical intervention, probably die. Logically, it would be expected that this trait should die out of a population due to natural selection.

However, another factor has to be thrown in to the mix, malaria, where a parasite enters the blood stream through a mosquito bite. This parasite cannot live in blood affected by the sickle cell disease.

All of a sudden, the demographic changes; individuals with no copies of the gene are likely to suffer malaria, those with two copies anemia.

Only the individuals with one copy of the gene will be unaffected, as they do not have enough cells affected to cause the anemic effects, but enough to deter the malaria parasite, the cost being that some of their offspring will suffer anemia or malaria susceptibility.

In a final support to the Red Queen Hypothesis [5], this mutation has occurred independently, at least four times in human history, with the same gene involved, indicating that this gene must have been preserved for some reason and parasitic pressure caused it to be manifested.

Summary

Species, whilst improving and evolving to be more successful must face some sort of pressure from parasites or predators in order to evolve, with sexual reproduction being one of the main factors. Whole ecosystems and food chains are kept in check by this evolutionary ‘arms race’ as described by the Red Queen Hypothesis.

Sexual reproduction also acts as a safeguard against extinction. If a natural disaster or epidemic almost wipes out a species, a large population is genetically diverse enough to allow some individuals to survive and the species can once again prosper.

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